Superconducting RF Facilities and Accomplishments at LANSCE

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1.0 Introduction

The Los Alamos Neutron Science Center (LANSCE) of the Los Alamos National Laboratory has a long history in Accelerator Technology, dating from the late '60s. The Superconducting RF (SRF) Laboratory started within the RF-Structures laboratory in the late 1980's. These SRF facilities were extensively renovated and enlarged during the Accelerator Production of Tritium Project in the late 1990s [Bibeau]. The result was a laboratory with the capacity for tuning, cleaning, and vertically-testing SRF elliptical and spoke cavities at 350, 700, 805 and 3000 MHz; and assembling cryomodules. When coupled with electron-beam welding and re-circulating, closed-loop buffered-chemical polishing facilities located at other sites on Los Alamos National Laboratory, a Room-Temperature Power-Coupler Test Bed elsewhere on LANSCE [Schmierer (I)], and a strong nucleus of experienced individuals, LANSCE has the self-contained capability to develop, design and build all critical elements of SRF prototype cryomodules, or to coordinate such activities with industry. The following list of world records emphasizes the quality of the SRF facilities and personnel at LANSCE. An asterisks (*) indicates records that have subsequently been exceeded.

- Highest Peak Electric Field with a 3-GHz Cavity - 85 MV/m (1992) [Diete]
- Fabrication of the First β=1, 805 MHz Elliptical Cavities (1993) [Rusnak]
- Highest Peak Electric Field with an 805-MHz Cavity - > 55 MV/m (1993) [Rusnak]
- Fabrication of the First Low-β Elliptical Cavities (1997) [Krawczyk]
- Highest CW Power through a Power Coupler – 1 MW (1999) [Schmierer (II)]
- Highest Low-β, 5-Cell, 700-MHz Cavity Peak Field - 41 MV/m (2000)* [Tajima (II)]
- Highest Spoke Cavity Accelerating Gradient - 13.5 MV/m (2002) [Tajima (III)]

What follows provides highlights of some of the LANSCE SRF facilities. The floor plan for the SRF Laboratory is given as Figure 1. Additional activities and publications may be found at the following website: http://laacg1.lanl.gov/scrflab/.

2.0 Facilities for Cleaning and Assembling Cavities

Over the years it has been consistently demonstrated that to maximize the performance of SRF cavities demands cleanliness levels meeting or exceeding those required for ultra-high vacuum work. In the LANSCE SRF Laboratory, cavities and cavity strings are cleaned and assembled in a dedicated 2,600-ft^2 (242 m^2), 10-feet (3-m) high cleanroom (Figure 1). Roughly ½ the area of the cleanroom is Class 100 or better (Figure 2 – Left), with the remainder Class 1000 or better. Originally designed for assembly of APT cryomodules, this is the largest SRF-dedicated cleanroom facility in the United States. As an example, the dimensions of this cleanroom are sufficient to permit assembly of a TESLA 8-cavity string (12-½–m long). Module egress from the cleanroom is through a 10-ft (3-m) wide by 8-ft (2.4-m) tall roll-up door located in the Class 1000 area.

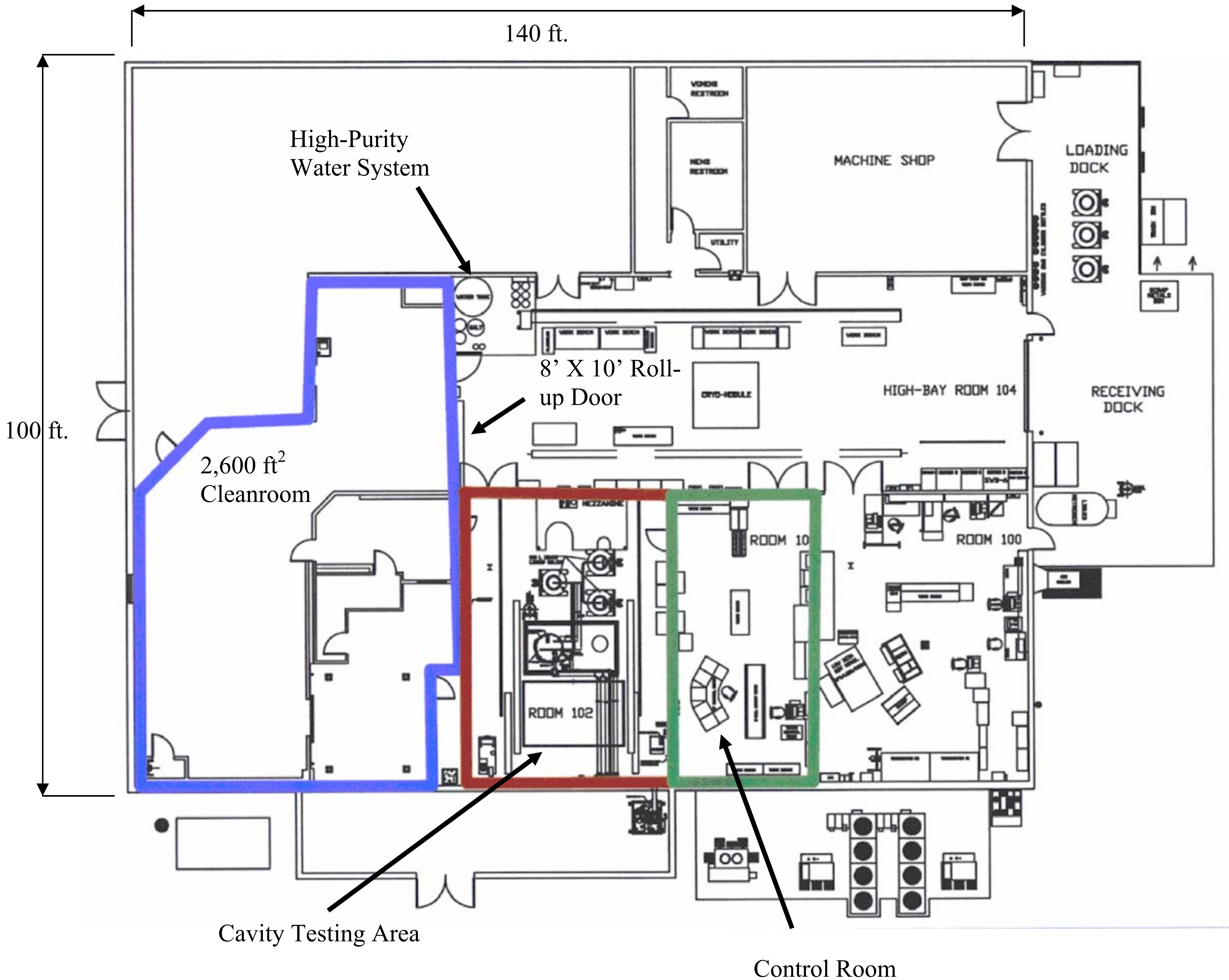

Figure 1: Floor plan for the LANSCE RF Structures Facilties. Highlighted areas are the LANSCE SRF Laboratory.


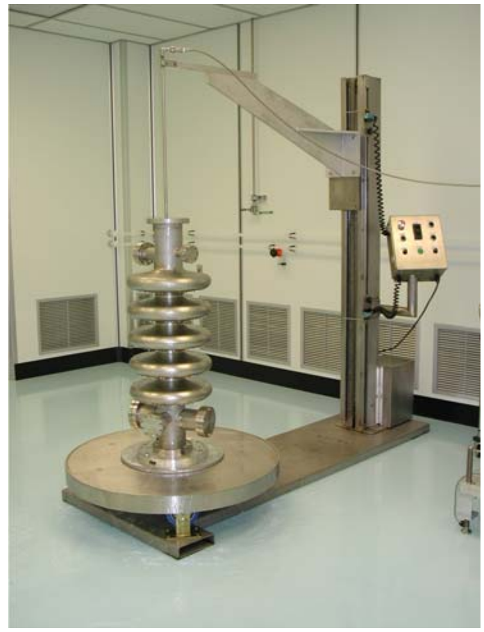

Figure 2: Left: The LANSCE Superconducting RF Laboratory's Class-100 Cleanroom area. Right: The high-pressure rinsing station demonstrated with a 5-cell, 0.64 beta, APT cavity (active length of 1.1 m with a 0.4-m diameter.)


Figure 3: Left: Ultra-pure water system. Right: Ultrasonic cleaning station located in the Class-1000 portion of the cleanroom.

A high-pressure rinsing system is located in the Class-100 portion of the cleanroom (Figure 2 – Right). This system is used to rinse particles and chemical residues from the inner surface of a cavity. It accomplishes this task by rotating a cavity on the turntable at ~ 30 rpm as water jets at 1,000-1,500 psi axially track up and down automatically. The cleanroom also contains a small, high-pressure, hand-held rinsing station for cleaning small parts.

Water for the high-pressure rinsing system is provided from an ultra-pure water system (Figure 3 – Left). This system is capable of producing de-ionized water at a rate of 2,000 gallons per day at a resistivity (purity) of > 18 MΩ·cm, with filtration for particulate less than 0.2 microns. The system includes a 1,500-gallon storage reservoir. By way of example, the current high-pressure rinsing requirements to process a single TESLA 9-cell cavity is ~ 2000 L (500 gallons).

Located in the Class-1000 portion of the cleanroom is an ultrasonic cleaning station (Figure 3 – Right). This station, which includes three 90-gallon baths with 40-kHz oscillators, is used to degrease, clean, and rinse the components for SC cavities and power couplers in the cleanroom.

3.0 Cavity Testing Facilities

Once a cavity is cleaned and assembled, the cavity's performance is typically evaluated in a "vertical" cryostat, so called because the cavity's axis is oriented vertically during testing as opposed to the final horizontal orientation in an accelerator. The sealed cavity is removed from the cleanroom, and mounted on one of two cryostat "inserts," a cryostat head with all thermal shielding, and cryogenic, vacuum and instrument penetrations required for testing (Figure 4 – Left). Once mounted, the cavity is inserted into a 38" (0.97-m) inner diameter, 10-foot (3-m) deep, liquid-nitrogen-shielded cryostat (Figure 4 – Right). The cryostat is shielded with warm mu-metal and with Helmholtz coils, reducing the earth's magnetic fields nominally to 5 milligauss along the lower 40 in. (1.02 m) of the cryostat's vertical axis. A 2-m long cavity can be tested with the present insert's thermal-shielding arrangement.

Figure 4: Left: Cryostat inserts, one with a 700 MHz, 5-cell, elliptical cavity, and the other with a 350 MHz spoke cavity. Right: The cryostat area. In the center is the 38" cryostat (covered). Above and to the left of this cryostat is a second cryostat with a 20" diameter. Shown also is the radiation shielding that covers the cryostat area during testing.

Testing is supported by the cryogenic system shown in the flowsheet given as Figure 5. The cryostat, which nominally holds 1,500 L of liquid helium at the start of testing, is dewar fed. To achieve 1.7 K, typically the lowest temperature reached during cavity characterization, the bath is pumped on by a roots blower backed by a pair of rotary pumps.

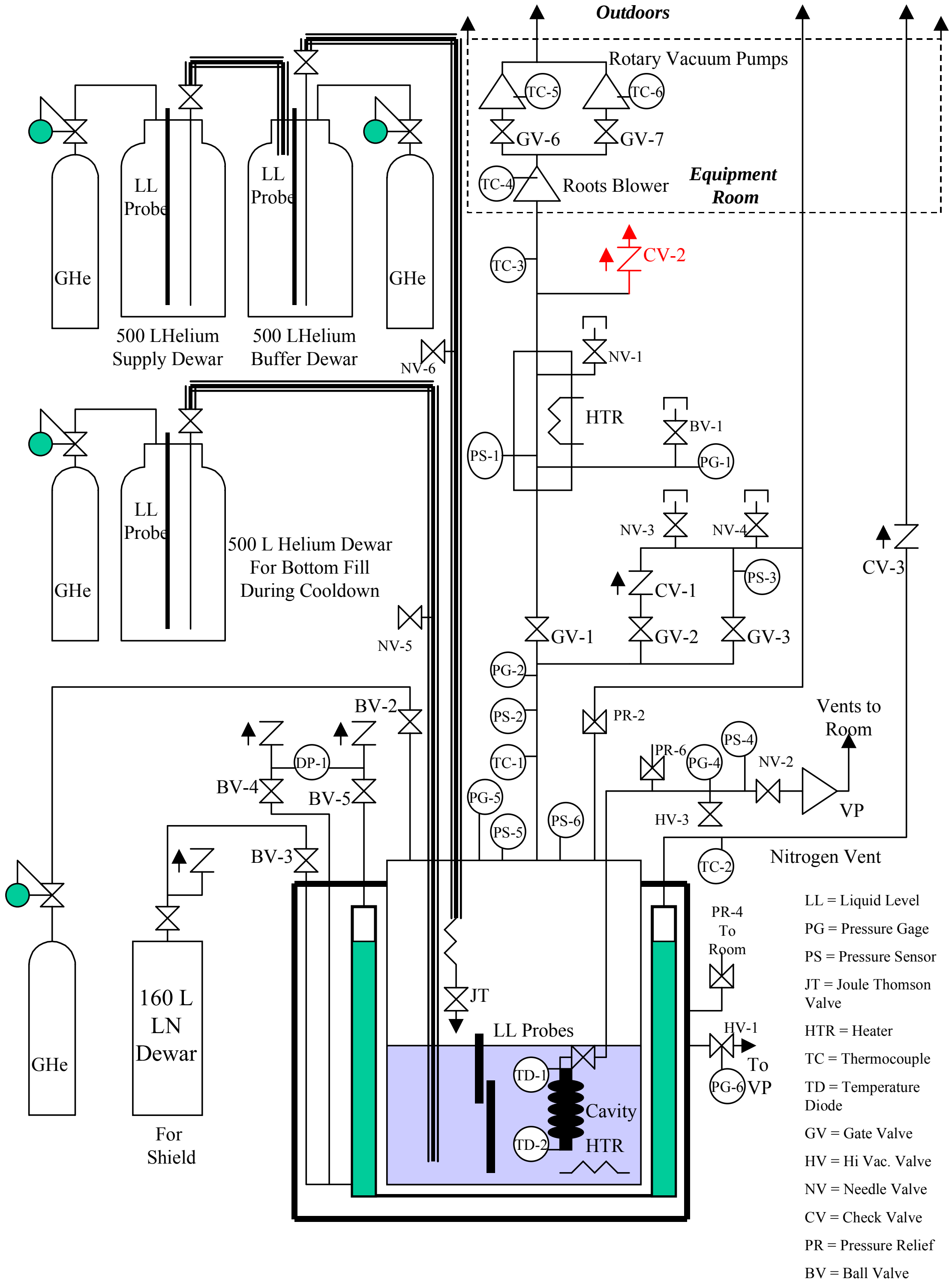

Figure 5: Cryosystem flowsheet for cavity testing.

A flowchart displaying the RF system used to support cavity testing is given as Figure 6. The system features a stable super-heterodyne circuit, which allows accurate and rapid cavity characterization of the Q and field levels. Labview is used for data-acquisition and presentation.

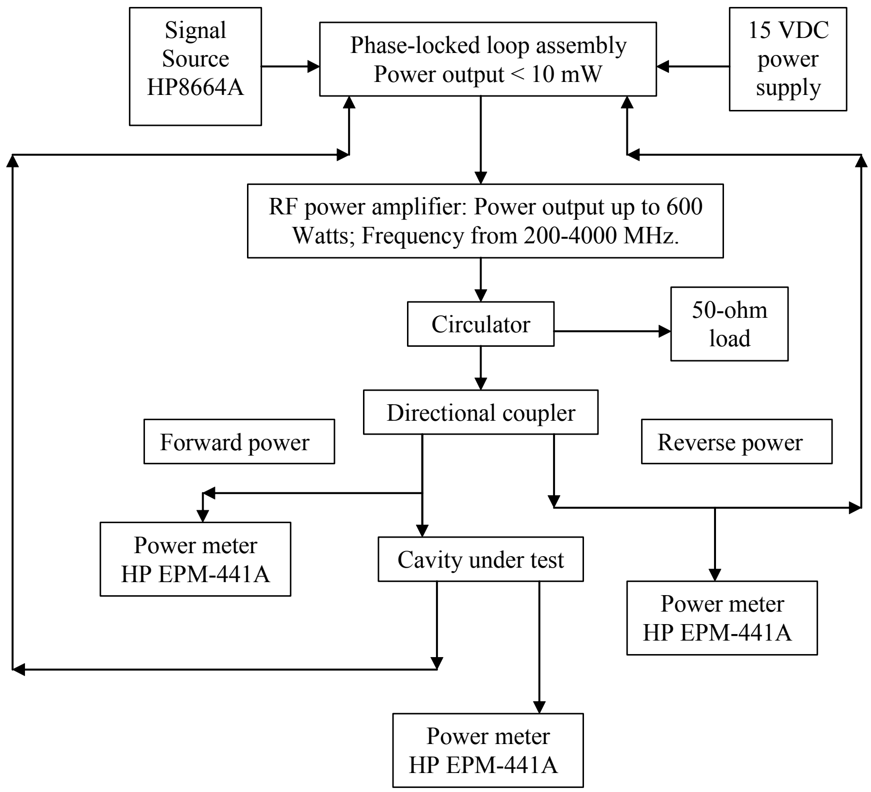

Figure 6: Flowchart characterizing the RF infrastructure required for SRF cavity testing.

4.0 Ancillary Equipment

4.1 Located within the LANSCE SRF Laboratory

The SRF Laboratory also has a bench-tuning system (Figure 7). Originally this device was designed to tune multi-cell elliptical cavities and is used to adjust their field levels to a desired flatness. The tuning bench has removable tuning plates that allow using the bench for different cavity geometries as long as these fit into the bench-frame. Recently, the bench tuner was successfully modified to accommodate 350-MHz spoke cavities [Tajima (I)].

4.2 Located within the LANL Materials Science and Technology Division

Located within the Materials Science and Technology (MST) Division is a temperature-controlled, re-circulating buffered-chemical polishing system that can currently

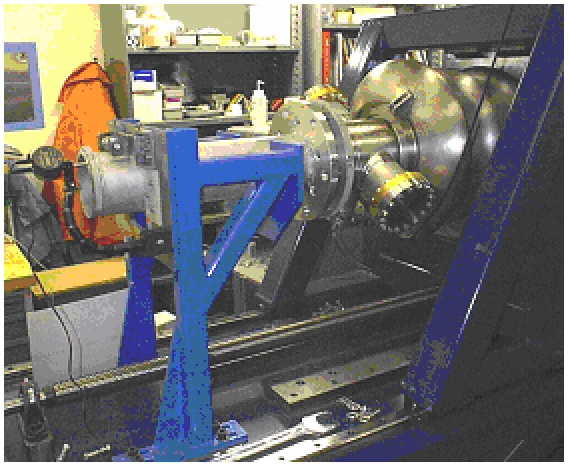

Figure 7: Bench tuner for elliptical and spoke cavities. Left: With an elliptical cavity. Right: With a spoke cavity.

accommodate multicell, 700-MHz elliptical and 350-MHz spoke niobium cavities. A chiller is used to keep the temperature of the acid below 15˚ C during the polishing process. The system features a rapid fill and rinse cycle that stops the etching process. The VCP system is shown in Figure 8.

MST also operates a high-voltage, e-beam welding system. This system has been used to weld virtually all the elliptical, single-cell, niobium cavities designed by LANL, and the first prototype of the Accelerator Production of Tritium (APT) 700 MHz, 5-cell, 0.64-beta cavity.

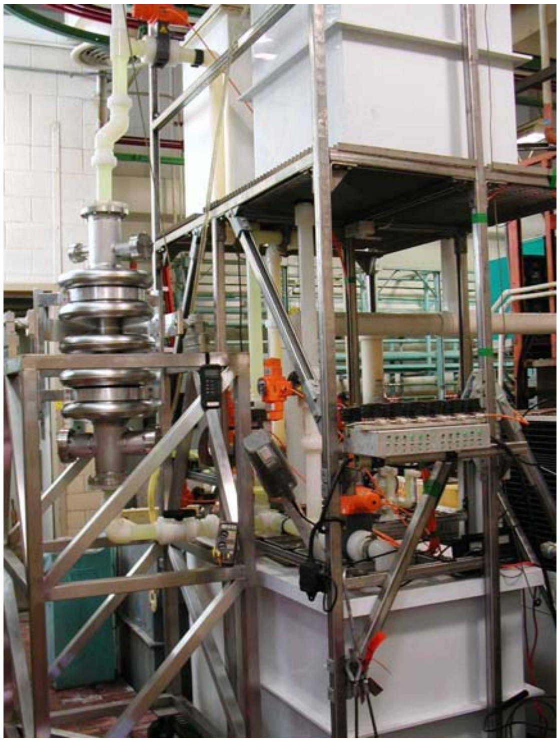

Figure 8: MST's BCP system polishing a 5-cell APT cavity.

5.0 References

Bibeau, R., et al., *Status of the LANL Activities in the Field of RF Superconductivity*, Proceedings of the 9th Workshop on RF Superconductivity, Santa Fe, NM November, 1999.

Krawczyk, F., et al., *Superconducting Cavities for the APT Accelerator*, LA-UR-97-1700, Proceedings of the 1997 Particle Accelerator Conference, Vancouver, B.C., Canada, 12-16 May, 1997.

Diete, W., et al., *High Temperature Heat Treatment of 3 GHz Niobium Cavities*, 1992 Linear Accelerator Conference Proceedings, Ottawa, Ontario, Canada, August 24-28, 1992, p. 722.

Rusnak, B., et al., Status of RF Superconductivity at Los Alamos National Laboratory, Proceedings of the 6th Workshop on RF Superconductivity, CEBAF, Newport News, VA, October 4-8, 1993, p. 145.

Schmierer (I), E.N., et al., *Testing Status of the Superconducting RF Power Coupler for the APT Accelerator*, Proceedings of the 9th Workshop on RF Superconductivity, Santa Fe, NM, November, 1999.

Schmierer (II), E.N., et al., *High-Power Testing of the APT Power Coupler*, LA-UR-00-3843, XX International Linac Conference, Monterey, CA, August 21-25, 2000.

Tajima (I), T., *Results of Room Temperature Tests on ANL Spoke Cavity (340 MHz, Beta= 0.291)*, LA-UR-01-3162, Los Alamos National Laboratory, Los Alamos, NM, April 23, 2001.

Tajima (II), T., et al., *Results of Vertical Tests with 700-MHz 5-Cell (beta=0.64) Superconducting Cavities Developed for APT*, LA-UR-00-4949, Los Alamos National Laboratory, Los Alamos, NM (2000).

Tajima (III), T., et al., *Results of Two LANL β=0.175, 350-MHz, 2-Gap Spoke Cavities,* LA-UR-03-3081, Particle Accelerator Conference, Portland, OR, May 12-16, 2003.